APPENDIX C

APPENDIX C to Cree's Motion No. 2
'618 PATENT CLAIMS 1 AND 4 ANTICIPATED BY THE CROWDER ARTICLE
INCLUDING DR. SHEALY'S ADMISSIONS REGARDING ANTICIPATION[1]

Claim Limitation[2]	Disclosure in the Crowder Article [Exh. 15]	Dr. Shealy's Testimony Establishing the Crowder Article Discloses Each Limitation [Exh.10]
1[A] A process for non-equilibrium incorporation of a dopant into a crystal of a wide band gap semiconductor comprising the steps of **Court's construction** wide band gap: "a band gap of at least 1.4 electron volts" non-equilibrium incorporation of a dopant: "incorporation of a dopant in excess of its	The Crowder Article discloses a method for making Zinc Telluride (ZnTe), a wide band-gap semiconductor having a band-gap of ~2.4 eV "The maximum energy of rare-earth fluorescence which can be observed is limited by the band gap of the host lattice. For ZnTe at 5 K, this is 2.39 eV." (p. 568; p. 570, Table II). The Crowder Article discloses that ZnTe was doped with a rare earth element, erbium (Er) and either lithium (Li) or phosphorus (P). "In this paper we report on the luminescence and EPR studies of Er^{+3} in ZnTe. The influence of different charge-compensation mechanisms are examined in ZnTe(Er), ZnTe(Er,Li), and ZnTe(Er,P) single crystals." (p. 568)	Q: Did they [Crowder] grow zinc telluride crystals? A: I believe so. Q: Is zinc telluride a wide-band gap semiconductor? A: Yes. Shealy Depo. Tr. (Sept. 24, 2009) at 315:5-10. In accordance with the Court's construction of "non-equilibrium incorporation of a dopant," Dr. Shealy testified that the concentration (solubility) of erbium (Er) in the ZnTe increased as a result of co-doping with both erbium and lithium. See Dr. Shealy's testimony cited in Element 1[F] below (concentration of Er increased from about 10^{16} to over 10^{17} per cubic centimeter). Q: Can you explain why the co-doping of the zinc

[1] B.L. Crowder et al., *EPR and Luminescence Studies of Er+3 in Acceptor-Doped ZnTe*, Physical Review, Vol. 181, No. 2, May 1969 at pp. 567-573 (Radulescu Decl. Exh. 15).

[2] For the Court's reference, Judge Connor's claim constructions are set forth below each limitation in which they appear.

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equilibrium solubility at a particular temperature and concentration of compensating species" dopant: "an impurity added to a semiconductor material to alter its electronic properties"	The Crowder Article discloses that the introduction of Er and Li resulted in hole concentrations as high as $1x10^{17}$ cm^{-3}: "ZnTe(Er, Li) as grown exhibited room-temperature hole concentrations of about $1x10^{17}$ cm^{-3}." (p. 570) This hole concentration is within the range of "non-equilibrium" dopant concentrations taught in the '618 patent. (Compare '618 patent at 3:38-43 ["in the range between 10^{17} and 10^{18} per cc^3"]). The Crowder Article discloses the non-equilibrium incorporation of a dopant (Er) by co-doping ZnTe with Er and either Li or P: "Upon zinc firing and rapid quenching, the behavior of ZnTe(Er) is quite similar to that of undoped ZnTe, with net acceptor concentrations of the order of 3 to $5x10^{16}$ cm^{-3} being observed. The amount of Er^{+3} soluble in ZnTe(Er) crystals is therefore most likely between 10^{15} and 10^{16} cm^{-3}. From the strength of the EPR signal, the concentration of Er^{+3} in ZnTe(Er,Li) and in ZnTe(Er,P) samples is of the order of 10^{17} cm^{-3}."(p.573, left col.)	telluride with lithium increased the concentration of the erbium in the zinc telluride? [objection] A: Well, one explanation would be the compensating effect, you know, increasing the solubility. Shealy Depo. Tr. (Sept. 24, 2009) at 329:3-11.

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	This result is consistent with the '618 patent's statement that co-doping with compensating species inherently results in non-equilibrium incorporation. ('618 patent at 2:1-5).	
1[B] treating the crystal in the presence of first and second compensating dopants of different mobilities **Court's construction** treating the crystal: "subjecting the crystal to a process which may occur during its growth" compensating dopant: "a dopant which provides an acceptor in n-type material or a donor in p-type material"	The Crowder Article discloses that the ZnTe layer was grown in the presence of Er (the "less mobile" dopant) and Li (a "more mobile" dopant): "In this paper we report on the luminescence and EPR studies of Er^{+3} in ZnTe. The influence of different charge-compensation mechanisms are examined in ZnTe(Er), ZnTe(Er,Li), and ZnTe(Er,P) single crystals." (p. 568, left col.). "The single crystals of ZnTe used in these studies were grown by Kucza. They were grown from a melt containing an excess of 25 mole% Te, 0.1 mole% of the desired rare-earth metal, and 0.1 mole% of either Li or P, or with no intentionally added co-dopant." (p. 569, left col). The Crowder Article discloses that Er acts as a donor dopant: "The electrical properties of ZnTe(Er) as	Q: Does Crowder disclose introducing erbium atoms into zinc telluride during growth? A: Yes. Q: Does Crowder disclose introducing lithium atoms into zinc telluride during growth? A: I don't think he's describing it as lithium alone. But in the experimental section he's introducing erbium and lithium together in there. Shealy Depo. Tr. (Sept. 24, 2009) at 316:7-17. Q: Is erbium less mobile than lithium in zinc telluride? A: Based on size considerations, you would assume it is. Shealy Depo. Tr. (Sept. 24, 2009) at 326:13-16. Q: And do you believe, or do you understand that the paper describes erbium as having donor activity? A: It seems to describe erbium as a multivalent donor species, yes. Q: And it also describes lithium as a compensating acceptor?

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	grown indicate that Er is indeed acting as a donor species, since these samples are semi-insulating." (p.573, left col.) Furthermore, the '618 patent claims that in n-type ZnTe, Li is more mobile than Cl. '618 Patent at 4:26-29 ("because of its larger ionic size, chlorine will be less mobile than will the lithium). Thus, according to the '618 patent, because of its larger ionic size, Er will be less mobile than Li. Moreover, one of skill in the art at the time the application was filed would understand that Li is more mobile than Er.	A: Yes, there's also speculation, certainly in zinc telluride that interstitial lithium can also act as a donor. [ ] Q: But you agree that the paper describes these two dopants as compensating dopants? A: Yes, I do. Q: And that's supplemented by at least the third sentence of section 1 entitled "Introduction"? A: (Document review.) Yes, it just describes that the situation is even more complex. Because the erbium has two -- it says the rare-earth ion has been found on two sites, substitutional cation and an interstitial site. Q: And on at least one of those sites, we know that lithium is a compensating dopant to erbium. Is that correct? A: That's what the paper suggests, yes. Shealy Depo. Tr. (Sept. 24, 2009) at 317:24-319:10.
1[C] for introducing substantially equal amounts of the two dopants into at least a portion of the crystal **Court's construction** substantially equal amounts:	Crowder discloses growth of ZnTe crystals from a melt containing substantially equal amounts (namely, the same amounts) of co-dopants Er and Li or co-dopants Er and P – specifically, 0.1 mole% of each dopant. "The single crystals of ZnTe used in these studies were grown by Kucza. They were grown from a melt containing an excess of 25 mole% Te, **0.1 mole%**	Q: Right. And you agree that he's describing the introduction of .1 molar percent of erbium together with .1 molar percent of either lithium or phosphorus as described in the second sentence of the section number 3 labeled, "Experimental" on page 569? A: He describes equal molar concentrations of the rare earth metal, erbium in this case, and the lithium or phosphorus, depending on which soup

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approximately equal molar quantities dopant: "an impurity added to a semiconductor material to alter its electronic properties"	**of the desired rare-earth metal**, and **0.1 mole% of either Li or P**, or with no intentionally added co-dopant." (p. 569, left col.). The '618 patent alleges that "[a]s long as the amounts of each [dopant] in the melt are approximately equal, because of strong compensating effects in such wide band gap crystals, substantially equal amounts of the two dopants will be introduced into the crystal." '618 patent, col. 3, lines 43-47.	he's making. Shealy Depo. Tr. (Sept. 24, 2009) 316:18-317:5 Q: Do you agree that in bulk crystal growth, when you introduce equal amounts by molar quantities of dopants into the melt, you get out quality [*sic*, equal] amounts by molar quantities in the as-grown crystal? A: Certainly not when you're polling crystals, but this is not that kind of experiment. So if the entire melt is consumed and solidifies and there's no segregation of the impurities on the surface of the crystal, but even if there is, if you want to average that then, you know, the number of those quantities going into the ampules is equal to what is coming out. Q: Do you agree that Crowder teaches introduction of equal molar amounts into the crystal of erbium and lithium? A: Taken on average, yes. Shealy Depo. Tr. (Sept. 24, 2009) at 321:7-322:2.
1[D] such that the concentration of the less mobile of the two dopants in said portion of the crystal is in excess of the	The Crowder Article discloses that co-doping with Li (the more mobile dopant) and Er (the less mobile dopant) improves the solubility of Er in the ZnTe crystal. "Er^{+3} can be incorporated in the ZnTe	Q: Okay. Do you agree that by introducing equal amounts of erbium and lithium into the zinc telluride by molar quantity, that the erbium concentration increased as a result of being co-doped with lithium? A: That's what it says.

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solubility therein of the less mobile dopant in the absence of the more mobile of the two dopants, **Court's construction** in excess of the solubility: "the concentration of the less mobile dopant is greater than its concentration in the absence of the more mobile dopant" dopant: "an impurity added to a semiconductor material to alter its electronic properties"	lattice in significant concentrations by co-doping with an acceptor species." (Abstract) "The absence of detectable resonances due to Er^{+3} in ZnTe(Er) samples implies that the Er^{+3} concentration which is soluble in the ZnTe lattice is considerably lower than that present in either ZnTe(Er,P), or ZnTe(Er,Li)." (p.573, left col.). The Crowder Article further discloses that the concentration of Er in ZnTe co-doped with Er and Li is at least ten times higher (i.e., an order of magnitude) than in ZnTe doped with Er alone: "Upon zinc firing and rapid quenching, the behavior of ZnTe(Er) is quite similar to that of undoped ZnTe, with net acceptor concentrations of the order of 3 to $5x10^{16}$ cm^{-3} being observed. The amount of Er^{+3} soluble in ZnTe(Er) crystals is therefore most likely between 10^{15} and 10^{16} cm^{-3}. From the strength of the EPR signal, the concentration of Er^{+3} in ZnTe(Er,Li) and in ZnTe(Er,P) samples is of the order of 10^{17} cm^{-3}." (p.573, left col.).	Q: And do you agree that the erbium concentration without being co-doped with lithium was on the order of 10 to the 15th to 10 to the 16th per cubic centimeter? A: Yes, I guess that's their description. They're substantially equal. Shealy Depo. Tr. (Sept. 24, 2009) at 323:11-23; *see* Shealy Depo. Tr. (Sept. 24, 2009) at 330:17-24 (testifying that the solubility of erbium in ZnSe without co-doping of lithium is "10 to the 15, on the order of.") Q: Do you agree then by co-doping the zinc telluride with both erbium and lithium resulted in an increase in the concentration from about 10 to the 16th per cubic centimeter to over 10 to the 17th per cubic centimeter? A: (Document review.) I believe, based on this discussion, that the concentration of the erbium went up. The technique they're using to measure it is EPR. You know, I, I know that's sensitive to the -- I don't think it's as quantitative as what we're normally, the techniques we normally use to measure impurities Q: Right. But can you give us an approximate range on how much the erbium concentration increased as a result of the co-doping with lithium?

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		A: Based on the face value of this, at least a factor of 10. Shealy Depo. Tr. (Sept. 24, 2009) at 324:6:-325:4. Q: Can you explain why the co-doping of the zinc telluride with lithium increased the concentration of the erbium in the zinc telluride? [Objection] A: Well, one explanation would be the compensating effect, you know, increasing the solubility. Shealy Depo. Tr. (Sept. 24, 2009) at 329:3-11.
1[E] and then heating the crystal to remove therefrom preferentially the more mobile of the two dopants **Court's construction** remove: "taking away from the crystal an effective portion" dopant: "an impurity added to a semiconductor material to alter its	The Crowder Article discloses that, after growth of the co-doped ZnTe crystal, the crystal was subjected to heat treatments to preferentially remove Li (the more mobile dopant) from the crystal: "**Thermal treatments** which are known to remove Li from electrically active centers in ZnTe greatly increase the strength of the cubic spectrum and greatly reduce the strength of the trigonal spectrum." (Abstract). "**Subsequent heat treatments** of portions of these single crystals were conducted in sealed, evacuated (to about 10^{-6} Torr) quartz ampoules. If a known	Q: Does the reference disclose that the zinc telluride erbium lithium was subjected to a heat treatment to remove lithium? A: It says it was subjected to a heat treatment which is known to remove lithium, based on a reference 11. Shealy Depo. Tr. (Sept. 24, 2009) at 328:3-9. Q: Right. Do you agree that the second sentence of the abstract discloses that the zinc telluride was subjected to a thermal treatment which is known to remove lithium from electrically active centers in zinc telluride? A: I agree that's what it says.

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electronic properties"	Zn overpressure was desired, a chip of high purity Zn was placed in the sample ampoule in a quartz plug. If liquid extraction was desired, the sample was held under liquid Zn by a quartz finger. Samples which were heat-treated were quenched by immersing the ampoule in a water bath in order to freeze in that atomic disorder more characteristic of the elevated firing temperature. In the following discussion of experimental results, crystals which were fired in Zn vapor at 850°C for 2 to 4 h will be referred to as "zinc fired," crystals given similar treatment in a bath of liquid Zn will be referred to as "zinc extracted," and crystals which were annealed in vacuum at 250°C for several days will be referred to as "vacuum annealed."(p. 569, col. 1; also p. 570, col. 1) Moreover, the conditions for removing Li from doped ZnTe crystals (by heating the crystal at 850 C in Zn vapor) are within the range disclosed in the '618 patent. '618 patent, 3:51-62 (disclosing that "the lithium is preferentially removed from the epitaxial layer" by, for example, heating the crystal "in the range of between 600 C-1000 C in zinc vapor").	Shealy Depo. Tr. (Sept. 24, 2009) at 328:17-24.
1[F] whereby there is	The Crowder Article discloses that, after heating the	Q: Okay. Do you agree that by introducing equal

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left a non-equilibrium concentration of the less mobile dopant in said portion of the crystal.	ZnTe crystal to remove Li (the more mobile dopant), the crystal has a non-equilibrium concentration of Er (the less mobile dopant). "Upon zinc firing and rapid quenching, the behavior of ZnTe(Er) is quite similar to that of undoped ZnTe, with net acceptor concentrations of the order of 3 to $5x10^{16}$ cm^{-3} being observed. The amount of Er^{+3} soluble in ZnTe(Er) crystals is therefore most likely between 10^{15} and 10^{16} cm^{-3}. From the strength of the EPR signal, the concentration of Er^{+3} in ZnTe(Er,Li) and in ZnTe(Er,P) samples is of the order of 10^{17} cm^{-3}." (p.573, left col.).	amounts of erbium and lithium into the zinc telluride by molar quantity, that the erbium concentration increased as a result of being co-doped with lithium? A: That's what it says. Q: And do you agree that the erbium concentration without being co-doped with lithium was on the order of 10 to the 15th to 10 to the 16th per cubic centimeter? A: Yes, I guess that's their description. They're substantially equal. Shealy Depo. Tr. (Sept. 24, 2009) at 323:11-23. Q: Do you agree then by co-doping the zinc telluride with both erbium and lithium resulted in an increase in the concentration from about 10 to the 16th per cubic centimeter to over 10 to the 17th per cubic centimeter? [Objection] A: (Document review) I believe, based on this discussion, that the concentration of the erbium went up. The technique they're using to measure it is EPR. You know, I, I know that's sensitive to the -- I don't think it's as quantitative as what we're normally, the techniques we normally use to measure impurities. Q: Right. But can you give us an approximate range on how much the erbium concentration increased as a result of the co-doping with

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		lithium? A: Based on the face value of this, at least a factor of 10. Shealy Depo. Tr. (Sept. 24, 2009) at 324:6-325:4. Q: Can you explain why the co-doping of the zinc telluride with lithium increased the concentration of the erbium in the zinc telluride? [objection] A: Well, one explanation would be the compensating effect, you know, increasing the solubility. Shealy Depo. Tr. (Sept. 24, 2009) at 329:3-11.
4. The process of claim 1 in which the more mobile dopant can move via interstitial sites and the less mobile dopant is at a substitutional site in the crystal.	The Crowder Article discloses a method in which the more mobile dopant (Li) can move via interstitial sites and the less mobile dopant (Er) is at a substantial site in the crystal. The Crowder Article discloses that Er can reside at a substitutional site. "To summarize the EPR results, the predominant sites at which Er^{+3} is found in ZnTe are as follows: site I (observed in ZnTe doped with either Li or P), an isolated **Er^{+3} on a substitutional Zn site**; site II (observed in P-doped ZnTe),	Q: Is erbium less mobile than lithium in zinc telluride? A: Based on size considerations, you would assume it is. Shealy Depo. Tr. (Sept. 24, 2009) at 326:13-16. Q: But you agree that the paper describes these two dopants as compensating dopants? A: Yes, I do. Q: And that's supplemented by at least the third sentence of section 1 entitled "Introduction"? A: (Document review.) Yes, it just describes that

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	a substituional Er^{+3} with a P atom on one of the four nearest-neighbor Te sites; and site III (observed in Li-doped ZnTe), an Er^{+3} in an interstitial site surrounded by six next-nearest-neighbor Te, three nearest-neighbor Zn, and one nearest-neighbor Li on a Zn site." (p. 572, right col.) The Crowder Article discloses that Li moves via an interstitial site: "Thermal treatments which are known to remove Li from electrically active centers in ZnTe greatly increase the strength of the cubic spectrum and greatly reduce the strength of the trigonal spectrum." (Abstract). "[T]he sample of ZnTe(Er, Li) was subjected to treatments which are known to remove Li from electrically active sites in ZnTe…." (p. 570, left col.)	the situation is even more complex. Because the erbium has two, it says the rare earth ion has been found on two sites, substitutional cation and an interstitial site. Shealy Depo. Tr. (Sept. 24, 2009) at 318:17-319:5.